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29 September 1982

USSR REPORT  
ENGINEERING AND EQUIPMENT

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## CONTENTS

## NUCLEAR ENERGY

Structural Materials for Fusion Reactors: Selection Problems.....	1
Effect of Linkage Between Reactor Core Parameters on Fuel Element Reliability Indicators.....	2
Automatic Equipment for Inspection of Irradiated Fuel Elements by Gamma-Scanning Method.....	2
Application of Direct Methods to Neutron-Physics Design of Reactors.....	3
Feasibility of Plutonium Determination During Gamma-Spectrometric Determination of Nuclear Fuel Burnup.....	4
Buildup of Plutonium Isotopes in Uranium Fuel of Hybrid Fusion Reactor.....	4
Stochastic Characteristics of Peak-Power Margins in Evaporator Channels of Reactors in Beloyarskaya AES Based on Analysis of Operating Data.....	5

## NON-NUCLEAR ENERGY

Concentrator Mirrors for Operation With High-Current Solar Cells.....	6
Solar Power Plants: Heat Transfer and Thermal Optimization for Generating Saturated Steam.....	7
High-Efficiency Silicon Photoelectric Cells and Outlook for Their Improvement.....	7

Operating Experience With Silicon-Type Converter Substations....	8
CONSTRUCTION	
Design of Pile Foundations for Building on Frozen Ground.....	10
INDUSTRIAL TECHNOLOGY	
Optothyristor Switch With LED Display.....	11
Control of Linear Electric Drive for Addressable Conveyer.....	14
New Kinematic Linkages and Designs for Manipulator Servomechanisms.....	15
TURBINE AND ENGINE DESIGN	
Requirements Imposed on Modern Mathematical Models of Gas Turbine Engines: Part 2.....	16
Calculation of Pro Rata Performance Indicators of Cooled High-Temperature Gas Turbine Engines.....	16
Analytical Profiling of Turbine Blades.....	17
Dependence of Bleeder Tap Performance on Distance Between Turbine Stages.....	18
Design Analysis of Standard Cylindrical Medium-Pressure Stage of Steam Power Turbines.....	18
Theoretical and Experimental Design Study of Runners for Radial-Axial High-Speed Water Turbines.....	19
Simulation of Heating of Runner of Steam Turbine in Two- Dimensional Temperature Field Under Varying Conditions of Heat Transfer From Hot Steam.....	20
Improving Efficiency of Condensation-Type and Regenerative- Type Power Steam Turbines.....	21
NAVIGATION AND GUIDANCE SYSTEMS	
Optimum Program of Aircraft Power Plant Control During Acceleration-Climb Period.....	22
Evaluating Efficiency of Nonstationary Discontinuous Aircraft Control Systems.....	22
Synthesis of Optimal Control for Spacecraft With Elastic Elements Under Random Perturbations.....	23

Stability of Maneuver Aircraft.....	24
HIGH-ENERGY DEVICES, OPTICS AND PHOTOGRAPHY	
Passive Q-Switching of CO <sub>2</sub> Laser by Means of Photochromic Filters Made of Heterocyclic Compounds.....	25
Effect of Perturbation in Active Medium on Frequency Instability of Emission From Stabilized Laser With External Absorbing Cell.....	26
FLUID MECHANICS	
Asymptotic Solution to Problem of Shock Wave in Hypersonic Stream Around Axisymmetric Blunt Bodies.....	27
Theory of Regular Fluctuations in Swirling Stream of Fluid.....	28
MECHANICS OF SOLIDS	
Nonlinear Vibrations of Plates in Longitudinal Magnetic Field.....	29
Theory of Thin Anisotropic Shells Made of Composite Materials.....	29
Design of Straight-Wing Shells.....	30
Design of Cylindrical Shell With Shape Imperfection for Stability Under Axial Compression on Basis of Buckling Pattern Established by Test Data Analysis.....	30
Ultimate Equilibrium of Cyclically Symmetric Shells.....	31
Calculation of Parameters of Solid-Body Orientation.....	32
Approach to Numerical Solution of Boundary-Value Problems in Statics of Flexible Shells.....	32
TESTING AND MATERIALS	
Wear Resistance of Gear Transmissions in Vacuum.....	34

UDC 620.1

STRUCTURAL MATERIALS FOR FUSION REACTORS: SELECTION PROBLEMS

Moscow VESTNIK AKADEMII NAUK SSSR in Russian No 3, Mar 82 pp 55-61

AGEYEV, N. V., academician, and IVANOV, L. I., doctor of physico-mathematical sciences

[Abstract] Selection of structural materials for the first wall of "INTOR" fusion reactors (developed by the Soviet Union jointly with the United States, Euratom and Japan under auspices of the International Agency for Atomic Energy) is based on several criteria. The material must have high radiation resistance and low residual radioactivity, have satisfactory mechanical and thermomechanical properties, be refractory, be compatible with the coolant, also be technologically feasible. The material must, furthermore, not contaminate the thermonuclear plasma when bombarded by neutron, ion, and other particle fluxes under severe thermal conditions. A great deal of research is being done at the Institute of Metallurgy imeni A. A. Baykov (USSR Academy of Sciences) and, on the basis of microstructural analysis as well as extensive mechanical tests, including important creep tests, the selection has been narrowed down to a few metals: stainless steel, aluminum, titanium, vanadium, manganese, columbium, molybdenum, tungsten. With respect to thermoelasticity, which characterizes the ability of a material to remove a heat load without fracture and embrittlement, alloys of copper, molybdenum, or aluminum are most suitable and stainless steels are least suitable for this application. These studies are made by simulation methods, the only ones capable of yielding results in a short time but needing further refinement for the solution of still many engineering and material problems. Figures 7, table 1, references 7: 4 Russian, 3 Western.  
[257-2415]

## EFFECT OF LINKAGE BETWEEN REACTOR CORE PARAMETERS ON FUEL ELEMENT RELIABILITY INDICATORS

Moscow ATOMNAYA ENERGIYA in Russian Vol 52, No 5, May 82  
(manuscript received 6 Jul 81) pp 346-347

KURBATOV, I. M.

[Abstract] The temperature in a reactor core is a function of several mutually independent quantities randomly deviating from their nominal values, including technological, operational, and metrological parameters. The temperature distribution is accordingly subject to Lyapunov's central-limit theorem and the reliability of fuel elements its affects can be determined with the aid of Taylor series. This method of analysis is, for illustration, applied to the coolant temperature  $t_1 = t_0 + \frac{Q}{cG}$  ( $t_0$  - coolant temperature at channel entrance,  $Q$  - thermal power of reactor channel,  $G$  - coolant flow rate,  $c$  - specific heat of coolant), considering that the distributions tends toward a normal one and applying Cauchy's law to the quotient of two variables  $Q/G$ . Numerical calculations are shown for various likely values of the statistical characteristics. The precision of calculations is then extended by inclusion of additional temperature drops in the core. Figure 1, references 5 Russian.  
[264-2415]

UDC 621.397.13

## AUTOMATIC EQUIPMENT FOR INSPECTION OF IRRADIATED FUEL ELEMENTS BY GAMMA-SCANNING METHOD

Moscow ATOMNAYA ENERGIYA in Russian Vol 52, No 5, May 82  
(manuscript received 4 May 81) pp 336-337

GALKOV, V. I., KOROTKOV, V. P., MEL'NICHENKO, N. A., PESHKOV, V. P.,  
PROYMIN, G. S. and TARASOV, V. M.

[Abstract] An automatic device for inspection of fuel elements by the  $\gamma$ -scanning method has been built which includes program control and data analysis. Specimens of fuel elements are handled in a hot cell by an automatic manipulator, they are moved lengthwise and rotated in a carriage on a chassis by a stepper drive mechanism with speed regulation through the field of view of the collimator. The latter is of the slit type with adjustable width, consisting of a main unit and secondary units placed in front of Ge(Li) gamma-ray detectors (volumes up to 60 cm<sup>3</sup>) and Ge(Li) x-ray detectors (sensitive areas up to 5 mm<sup>2</sup>). The  $\gamma$ -spectrometer is a standard one of the full-absorption type. Detector output signals are amplified and shaped into pulses for an NTA-1024 amplitude analyzer and a recording instrument. The automatic programmable control system consists of a

programmer (compiler, comparator, counter), an indicator module (indicator, decoder, counter), a controller with outputs to the pulse analyzer and to the computer card puncher, also a master oscillator, a timer, and a stepper motor control. The equipment can operate discretely or continuously. It is periodically calibrated against standard spectrometric  $\gamma$ -sources, with proper correction for the given setup geometry. Theoretical and actual equipment performance parameters agree within 5%. Figures 3.  
[264-2415]

UDC 621.039.51

#### APPLICATION OF DIRECT METHODS TO NEUTRON-PHYSICS DESIGN OF REACTORS

Moscow ATOMNAYA ENERGIYA in Russian Vol 52, No 5, May 82  
(manuscript received 30 Mar 81) pp 316-320

ZEMSKOV, Ye. A. and ISAKOVA, L. Ya.

[Abstract] The authors have developed several algorithms of neutron-physics reactor design calculations in the group diffusion approximation, in cylindrical  $(r, \varphi)$ ,  $(r, z)$ , and  $(r, \varphi, z)$  coordinates respectively. The first one uses an integral scheme combining the Green method and the Bubnov-Galerkin method. The other two are based on single-channel synthesis of neutron fluxes. The fundamental equations of group diffusion are solved for effective-value boundary conditions at the KS surface of control rods and zero boundary conditions at their inside surface. Laplace-operator eigenfunctions are conveniently used as basis functions, reduction of the differential equations to a problem of linear algebra being facilitated by compact but segregate representation of intermediate data. This is demonstrated on the  $(r, \varphi)$  algorithm. Two-group diffusion coefficients for three reactor zones in a thermal reactor have been calculated accordingly, with the aid of a BESM-6 high-speed computer. A comparative evaluation of the results and those obtained by the finite-difference method indicates that these algorithms are as accurate in two-dimensional calculations and much more convenient for three-dimensional calculations respectively. Figures 2, table 1, references 8: 6 Russian, 2 Western.  
[264-2415]



# FEASIBILITY OF PLUTONIUM DETERMINATION DURING GAMMA-SPECTROMETRIC DETERMINATION OF NUCLEAR FUEL BURNUP

Moscow ATOMNAYA ENERGIYA in Russian Vol 52, No 5, May 82  
(manuscript received 5 Jun 81) pp 308-310

BULOVIC, V., KRTIL, J. and SUS, F., Institute of Nuclear Research, Rez, Czechoslovakia, MAKSIMOVIC, Z., Institute of Nuclear Sciences imeni B. Kidric, Vinca (Belgrade), Yugoslavia

[Abstract] The plutonium content in burned out fuel at the first Czechoslovak AES was estimated by two methods: directly by mass-spectrometry and indirectly from  $Ru^{106}$ ,  $Cs^{134}$ ,  $Cs^{137}$  determinations by  $\gamma$ -spectrometry. Specimens of fuel residue measuring  $0.1 \text{ cm}^3$  were cut from fuel elements with heating value of  $5 \text{ GW}\cdot\text{days/t}$ , after 645 days, and dissolved in  $6 \text{ M HCl} + 5\% \text{ H}_2\text{O}_2$  mixture. Evaluation and statistical analysis of data on activity of fission products and all transformation reactions affecting it indicate that  $\gamma$ -spectrometry yields the plutonium content within 10% accuracy. Figures 3, tables 3, references 4: 2 Yugoslav, 2 Western. [264-2415]

# BUILDUP OF PLUTONIUM ISOTOPES IN URANIUM FUEL OF HYBRID FUSION REACTOR

Moscow ATOMNAYA ENERGIYA in Russian Vol 52, No 5, May 82  
(manuscript received 8 Apr 81) pp 301-304

MARIN, S. V., ORLOV, V. V. and SHATALOV, G. Ye.

[Abstract] Plutonium production in hybrid fusion reactors is maximizable by use of blanket of depleted uranium with minimum number of nonfuel components and high-energy neutron spectrum. The isotope content of plutonium built up through efficient breeding of D-T reaction neutrons determines its usability as fuel and must, therefore, be established by special analysis. Calculations for this purpose have been made according to BLANK and BURNUP programs for a 2.65 yr irradiation period (average heating value  $4.5 \cdot 10^3 \text{ MW}\cdot\text{days/t}$ ,  $Pu^{239}$  buildup  $10 \text{ kg/t}$ ), with the aid of UKNDL and ENDL as well as domestic research data files. The availability of  $Pu^{236}$ ,  $Pu^{238}$ ,  $Pu^{239}$ ,  $Pu^{240}$ ,  $Pu^{241}$ ,  $U^{232}$  isotopes has been confirmed as a result and their distribution over the blanket thickness evaluated, with or without reflector and shield. The results agree fairly well with those obtained by other authors, Soviet and Western. Figure 1, tables 5, references 11: 6 Russian, 5 Western. [264-2415]

# STOCHASTIC CHARACTERISTICS OF PEAK-POWER MARGINS IN EVAPORATOR CHANNELS OF REACTORS IN BELOYARSKAYA AES BASED ON ANALYSIS OF OPERATING DATA

Minsk IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: ENERGETIKA in Russian No 4, Apr 82 (manuscript received 13 Jan 81) pp 49-54

VOLKOV, Yu. V., candidate of technical sciences, LYUBCHENKO, V. F., candidate of technical sciences, and SHEYNKMAN, A. G., candidate of technical sciences, Institute of Physics and Energetics, Beloyarskaya AES imeni I. V. Kurchatov

[Abstract] The reliability of fuel assemblies in boiling-channel nuclear reactors, which largely determines the economy of the AES, is characterized by the available peak-power margin in the evaporator channels. Here the stochastic characteristics of the peak-power margin are established on the basis of operating data from the Beloyarskaya AES. The quantitative indicator is the ratio  $X(t) = N_{cr}(t)/N(t)$  of maximum permissible (with respect to critical heat transfer) power to actual power in such a channel at time  $t$ , with  $N_{cr}$  depending on coolant pressure and flow rate as well as on coolant temperature at channel entrance. Various estimates of the margin distribution law according to standard methods of statistical analysis indicate that it must be

$$P\{Z \leq X\} = \Phi\{\gamma^{-0.5} \log[e^{\frac{\gamma}{2}} + y [e^{\gamma}(e^{\gamma} - 1)]^{0.5}]\}$$

with the probability integral

$$\Phi(X) = (2\pi)^{-0.5} \int_{-\infty}^{\frac{Z^2}{2}} e^{-\frac{z^2}{2}} dz$$

and the lower cutoff parameter

$$X_{co} = X - \sigma_X (e^{\gamma} - 1)^{-0.5}$$

$\gamma$  - dispersion of the random input perturbation process  $\xi(t)$ ,  $y(t) = [X(t) - X]/\sigma_X$ . The time autocorrelation function is

$$\rho(\tau) = e^{(-\alpha|\tau|)}$$

The standard deviation of peak-power margin is  $\sigma_X = \bar{\sigma}_X F^{-0.5}$  ( $\bar{\sigma}_X^2$  is the variance actual deviations in service,

$$F = \frac{2}{\pi} \tan^{-1} \left( \frac{\pi}{\alpha T} \right) - \text{ratio of variance of}$$

actual deviations at frequencies below Nyquist frequency to total variance). The random input perturbation process is a one-dimensional diffusion process, i.e., a Markov process continuous in space and time. Article recommended by Chair of Atomic Energy, Ural Polytechnic Institute. Figures 3, references 6 Russian. [266-2415]

## NON-NUCLEAR ENERGY

UDC 662.997:537.22(088.8)

### CONCENTRATOR MIRRORS FOR OPERATION WITH HIGH-CURRENT SOLAR CELLS

Tashkent GELIOTEKHNIKA in Russian No 1, Jan-Feb 82  
(manuscript received 2 Sep 81) pp 35-37

ALIMOV, A. K., USMANOV, M. U., UMAROV, G. Ya., ARIPOV, Kh. K.,  
LARIONOV, V. R. and RUMYANTSEV, V. D., Physico-Technical Institute  
imeni S. V. Starodubtsev, UzSSR Academy of Sciences; Physico-Technical  
Institute imeni A. F. Ioffe, USSR Academy of Sciences

[Abstract] A cost effectiveness study was made of circular paraboloidal mirrors and their radiation concentrating characteristics when operating with high-current heterostructural photoelectric cells. Specimens of such mirrors (thickness 3mm, diameter 500 mm, focal length 500 mm) were produced by the mollization process (flat sheet of window glass placed on cast-iron die, softened by uniform heating, bent to shape, cleaned mechanically and chemically, then metallized with reflective aluminum film and coated with protective enamel film on the back side). They were tested with two batteries of n-GaAs/p-GaAs/p<sup>+</sup>-AlGaAs photoelectric cells having active surfaces 10 and 17 mm in diameter respectively. The current-voltage characteristics of both batteries were measured under load, with various degrees of mirror utilization (only center third exposed, center third covered, whole mirror exposed) for battery with smaller cells and with various degrees of defocusing for battery with larger cells. The mirror efficiency and concentration factor were measured in each case. Experimental data and cost analysis indicate that such mirrors are used more advantageously with larger (17 mm in diameter) photoelectric cells. Electrical power output of 12.8 W is then feasible with optimum defocusing, the corresponding concentration factor being  $K = 508$ . The mollization process is the major cost item (1.56 rubles per mirror, at a production rate of 1 pc/h), the total cost of one mirror being 2.99 rubles. The mirror cost of operation in a solar power plant with AlGaAs photoelectric cells can thus be reduced to  $2.99/12.8 = 0.23$  rubles/W(el). The authors thank Zh. I. Alferov and S. A. Azimov for continuous attentiveness to this study. Figures 2, references 5 Russian.  
[239-2415]

# SOLAR POWER PLANTS: HEAT TRANSFER AND THERMAL OPTIMIZATION FOR GENERATING SATURATED STEAM

Tashkent GELIOTEKHNIKA in Russian No 1, Jan-Feb 82  
(manuscript received 21 Jan 81) pp 23-30

TEPLYAKOV, D. I. and APARISI, R. R., State Scientific Research Institute of Power Engineering imeni G. M. Krzhizhanovskiy

[Abstract] A mathematical model of radiative-convective heat transfer is proposed for thermal optimization of a steam generating solar power plant with plane heat exchanger roof. The equations for the steady-state thermal flux density include radiation component as well as convection and conduction components, with corresponding appropriate external boundary conditions. It is necessary and sufficient to account for convection on the exposed side of the roof, convection between roof and water (convection coefficient, according to Z. L. Miropol'skiy and M. Ye. Shitsman,  $\alpha_2 = 1.15q^{0.7}p^{0.43} = 1.59\Delta T_2^{2.33}p^{1.43}$ ,  $q$ - thermal flux density in  $W/m^2 \cdot ^\circ C$ ,  $p$ -steam pressure in atm,  $\Delta T_2 = T_2 - T_s$  excess temperature of roof above steam saturation point in  $^\circ C$ ), thermal resistance of the roof and thermal resistance of the insulation layer on the unexposed back side. It is also convenient to involve the equation of reverse heat balance, assuming a linear temperature profile across the insulation layer. Efficiency curve calculated accordingly are bounded on the lower-temperature side by the critical mode of pool boiling with attendant natural convection. The optimum concentration factor for the optical system can be determined on the basis of these curves. An experimental 3-5 MW solar electric power plant has been evaluated from this standpoint and its design found to be satisfactory for generating saturated steam at pressures of 30-40 atm (232-250 $^\circ C$ ). A pilot-utility 300 MW solar electric power plant is now being designed from this standpoint for generating standard superheated steam at pressures of 60-90 atm. Figures 3, table 1, references 10 Russian.  
[239-2415]

# HIGH-EFFICIENCY SILICON PHOTOELECTRIC CELLS AND OUTLOOK FOR THEIR IMPROVEMENT

Tashkent GELIOTEKHNIKA in Russian No 1, Jan-Feb 82  
(manuscript received 26 May 81) pp 3-7

BORDINA, N. M., GRIGOR'YEVA, G. M., DALETSKIY, G. S., ZHIDKOVA, Ye. V. and ZAYTSEVA, A. K., Order of Labor's Red Banner All-Union Scientific Research Institute of Current Sources

[Abstract] The performance characteristics of silicon photoelectric cells have already been improved appreciably by introduction of  $n^+p-p^+$  structures

with finely embedded p-n junction and contact shielding of the active surface. The key factor here is the doping process, specifically implantation of the purest possible phosphorus by controlled diffusion in a gas stream and optimization of the resulting impurity profile. Latest developments include the "violet" photoelectric cell (thickness 0.3-0.4 mm, electrical resistivity 1-2 ohm·cm, length of diffusion path for majority carriers 120-220  $\mu$ m), the "bilateral" photoelectric cell sensitive on both sides, the thin-base photoelectric cell (base thickness equal to or smaller than length of diffusion path for majority carriers), and the photoelectric cell with a p-i-n structure. Further improvement goals are decreasing the depth of the p-n junction to an ultrathin one of 0.2  $\mu$ m and using nonreflective grain-oriented surfaces as well as raw material with better electrophysical and structural characteristics. With these goals achieved, one should expect that photocurrent densities up to 40 mA/cm<sup>2</sup>, photo-emfs up to 620 mV, peak power densities up to 20 mW/cm<sup>2</sup> and current-voltage characteristics with an up to 80% range of flatness will become feasible. References 10: 8 Russian, 2 Western. [239-2415]

UDC 621.311.43/.44.004.1

#### OPERATING EXPERIENCE WITH SILICON-TYPE CONVERTER SUBSTATIONS

Moscow PROMYSHLENNAYA ENERGETIKA in Russian No 5, May 82 pp 24-26

SUTYUSHEV, V. S., engineer, and MAKEROV, V. P., engineer, Ust'-Kamenogorsk Titanium and Magnesium Combine

[Abstract] Silicon-type converter sets with water cooling are used as voltage supplies for extraction of nonferrous metals by the electrolytic process. The original AVP-141/1 silicon rectifier sets operating at the Ust'-Kamenogorsk titanium and magnesium combine have, since 1965, been modified for more reliable and economical performance. A major change was replacement of air cooling with water cooling. Use of plant water (hardness 5-11 mg-eq/l) eliminates the need for a closed loop to operate with distilled water. It also requires longer tubing, made of polyethylene, so that insulation resistance increases. Corrosion of heat exchanger and fittings is prevented by placement of sacrificial tubes of stainless steel at the cooler inlet and applying to them the positive potential. The life of these tubes is 2 years, deslaimation of the negative-potential side is required every 8-10 months. The water is purified by a filter containing seaweed, compost, and sand for trapping the coarse fraction. The fine fraction is let pass, as it hardly affects the cooler performance and, besides, can be easily removed during filter washdown with compressed air. The water pressure is checked by electrical manometers. The rectifier insulation, particularly vulnerable when exposed to plant water, is checked on the a.c. side with voltmeters. An alarm signal is sounded when the leakage current reaches 15 mA. Changes in the water hardness are monitored with a megohmmeter. Direct cooling with plant water is economical in terms of both water and

energy consumption. Vat insulation of 700-800 kilohms and rectifier insulation of 2 megohms ensure reliable operation of the plant, with a saving of at least 200,000 rubles/year. Figures 5.  
[251-2415]

## CONSTRUCTION

UDC 624.154.001.24

### DESIGN OF PILE FOUNDATIONS FOR BUILDING ON FROZEN GROUND

Moscow STROITEL'STVO TRUBOPROVODO in Russian No 4, Apr 82 pp 24-26

POLUEKTOV, V. Ye., Krasnoyarsk State Scientific Research Institute of Construction Planning, and RAYSKIY, O. A., Novosibirsk Industrial Institute

[Abstract] Reinforced concrete piles 32-32 cm in cross section were tested under static and dynamic horizontal loads, principally for supplementing scarce data on the embedment depth and restraint in permafrost layers. The tests were performed on the proving ground of the Novosibirsk Laboratory. The piles had been delivered from the Noril'sk plant: series A-5 made of M-300 concrete with class A-II steel rods 22 mm in diameter and series OG-1,2 made of M-300 concrete with class A-II steel rods 14 or 25 mm in diameter respectively. The piles were driven into ground holes 450 mm in diameter and then conglomerated with a lime-sand-water mixture, whereupon clay of laminar cryogenic texture containing 35 vol.% ice was poured in leaving 4.5 m up to the ground surface for dirt fill. Static horizontal load was applied with a turnbuckle in steps, from 10 to 50 kN, and held for 8 hours at each level. Testing under dynamic load involved measuring the change in natural vibration frequency. The results reveal that the depth over which a pile remains restrained in a permafrost layer under horizontal static load depends on the magnitude of the load but not on its duration. It also depends on the thickness of the seasonally thawing layer. For design of piles subject to dynamic horizontal loads, the depth of restraint in permafrost must be assumed to be equal to that thickness of the seasonally thawing layer. Figures 2, table 1, reference 1 Russian.  
[254-2415]

OPTOTHYRISTOR SWITCH WITH LED DISPLAY

Moscow MEKHAIZATSIYA I AVTOMATIZATSIYA PROIZVODSTVA in Russian No 5, May 82  
pp 10-11

[Article by engineers Yu. I. Gorban' and B. S. Limonov: "An Optothyristor Switch With LED Display in Cyclical Control Systems for Manipulators"]

[Text] The majority of automatic manipulators (AM's) produced--the PR 10I, "Tsiklon-3b", "Aida", MP-5, MP-9, et al.--belong to the first generation of manipulators with a cyclical system of control.

In these automatic manipulators, the control unit for the cyclical control device sends "activate-disable" commands to the link drives and production-equipment drives. The control unit is made up of relays of the contact and static types. If only a small number of electromechanical relays are required for the realization of logic functions, the device will be economical. In this case, the intermediate connections between the device's input and output are also simply worked out.

The use of a relay, however, is only suitable when there are less than 500 cycles per hour [1].

Semiconductors are employed where the operation of the switching devices is more intensive.

The frequency with which the electromagnets switch in the hydraulic and pneumatic valves of manipulators (except for the transport-type) is usually higher than the indicated limit. For this reason, contactless semiconductor elements are employed.

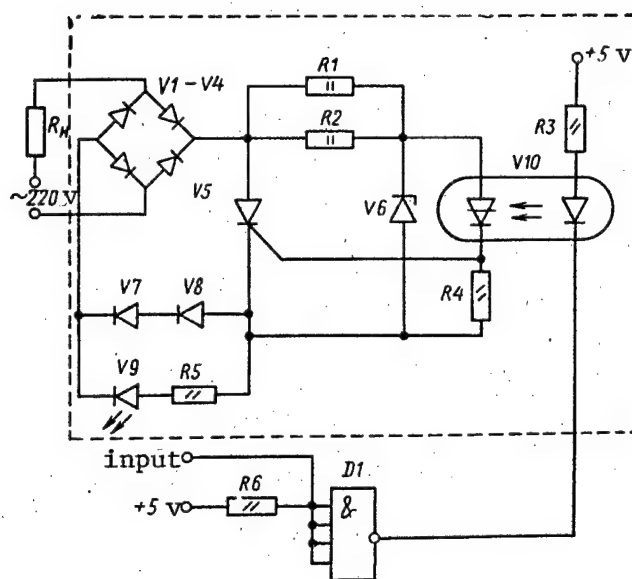
In order to control cyclical-type manipulators, industry manufactures standardized programmed-control devices--the UTsM-633, ETsPU-6030, ULP, et al. Control commands for the electromagnet valves in the manipulator and production commands in the devices are rendered in the form of direct current (24 V) or alternating current (110 V).

Contactless output amplifiers are made using TO-6.3 or AOU 103 optoelectronic thyristors. These make it possible to uncouple the input and output circuits, which is necessary with group control over the thyristors.

When new control devices are developed or when the load parameters do not coincide with the output-signal parameters of the devices used, it is necessary to seek new circuit designs for contactless key components.



The technical parameters of AOU 103 isolation transformers with a 200-V maximum amplitude alternating current limit their application.



The drawing presents a circuit for a thyristor switch. In its initial state, with an 0-level signal at the input of the microcircuit D1, the dynistor of the isolation transformer V10 is closed and current across the load  $R_L$  does not flow.

From the moment the action of the input ceases, the load remains switched on for a period of time not exceeding the duration of a half-cycle, since the dynistor closes the first time the supply-line voltage crosses 0.

In order to protect against overloads during transients that arise when inductive loads are disconnected, the photodynistor of optical isolation transformer V1 is activated through a divider made up of resistors R1, R2 and a stabistor V6.

Silicon diodes V7 and V8 are connected into the bridge diagonal in series with thyristor V5. LED V9 is connected parallel to them through resistor R5.

When current appears in the load circuit, the rectified current passes through the LED, causing the latter to glow. This indicates the presence of a load in the circuit.

The circuit described has been tested for noise immunity and voltage fluctuations in plant power supplies and has proven to be reliable.

A thyristor switching circuit has been integrated in manipulator-control equipment intended for the Omega Tractor Plant.

The universal nature of the circuit when matched with relay-type actuators makes it possible to use it in other cyclical control systems for automatic manipulators.

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CSO: 1861/250

## CONTROL OF LINEAR ELECTRIC DRIVE FOR ADDRESSABLE CONVEYER

Moscow VESTNIK MASHINOSTROYENIYA in Russian No 3, Mar 82 pp 9-12

KRAPIVIN, V. S., candidate of technical sciences

[Abstract] Linear electric motors are increasingly used as drives for in-plant movements of industrial robots. Such addressable conveyer robots are characterized by quick response, high velocity (at least 0.5 m/s) and high positioning accuracy (within tenths and even hundredths of a millimeter). Here a linear step motor is considered whose outer primary structure carrying the power coils between magnetically soft steel rings serves as the moving element and the inner secondary structure consisting of lengthwise alternating magnetically soft and nonmagnetic segments remains stationary and acts as guide rod. The motion of the primary is controlled with step sensors mounted in it or outside. Coil switching is controlled, optimally with respect to response speed, on the basis of start-stop dynamics and the corresponding second-order differential equations. The algorithm of control involves, accordingly, two differentiations. The feedback control loop for implementing this algorithm has been designed, assuming negligible inertia of the robot displacement transducer and the amplifier. The control system includes, in addition to five step sensors and the robot displacement transducer, also a stepping speed regulator and an acceleration regulator. Signals from the step sensors are added and then sent to a time-to-pulse converter. The acceleration regulator consists of a two-stage differentiating filter, an acceleration presetter, a comparator, a corrector, and an amplifier with a subdiscontinuous characteristic. Its operation is programmable. Figures 4, references 4: 3 Russian, 1 Czech, [253-2415]

## NEW KINEMATIC LINKAGES AND DESIGNS FOR MANIPULATOR SERVOMECHANISMS

Moscow VESTNIK MASHINOSTROYENIYA in Russian No 3, Mar 82 pp 7-9

GVOZDEV, Yu. F., engineer

[Abstract] Four new linkages for manipulator servomechanisms have been invented which enlarge the service range. They provide the required degrees of freedom with high efficacy and efficiency, high grip accuracy and kinematic stiffness, and without "dead" zones. The basic first variant with one translational degree of freedom consists of four links in series hinge-jointed to one another and at the base. The first link is coupled to a drive through a gear transmission, the others have built-in gear transmissions. The second variant with one translational degree of freedom consists of three such links joined pairwise through intermediate links with built-in pinion pairs. The third variant with one rotational and two translational degrees of freedom has an auxiliary gear transmission added to the first link at the base. The fourth variant with three translational degrees of freedom has the three main links with gear transmission joined successively through intermediate links with orthogonal conic gear transmissions. The gist of the design in each case is setting the proper gear ratios. Figures 4, references 2 Russian.

[253-2415]

## TURBINE AND ENGINE DESIGN

UDC 629.7.036.3.001

### REQUIREMENTS IMPOSED ON MODERN MATHEMATICAL MODELS OF GAS TURBINE ENGINES: PART 2

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA  
in Russian No 1, Jan-Mar 82 (manuscript received 11 Nov 79) pp 99-102

MATS, E. B. and TUNAKOV, A. P.

[Abstract] Part 1 of this article (AVIATIONNAYA TEKHNIKA No 3, 1981) enumerated the first group of 11 requirements that modern mathematical models of gas turbine engines must meet. Part 2 enumerates the second group of 10 requirements. They are: modular structure, universality of engine design, multimodality of engine operation, adaptability to engine design for ambient conditions not automatically controllable, adaptability to implementation of any control program, universality of engine application, suitability for automated design, correctability and immunity to shutdown of calculations with nonrealistic parameter values, and versatility with respect to fuel base. So far no model satisfactorily meeting all 21 requirements has yet been developed, but two are already available that meet most of them. Figure 1, references 2 Russian.  
[262-2415]

UDC 621.438

### CALCULATION OF PRO RATA PERFORMANCE INDICATORS OF COOLED HIGH-TEMPERATURE GAS TURBINE ENGINES

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA  
in Russian No 1, Jan-Mar 82 (manuscript received 29 May 81) pp 89-95

LOKAY, V. I. and ZAKIROV, M. U.

[Abstract] Specific air rate and fuel rate as well as enthalpy drop are calculated for various types of high-temperature gas turbine engines, taking into account the cooling requirement and its effect on performance. The calculations are based on formulas for turbojet engines, turbojet-compressor

engines, and turboprop engines with low-pressure and high-pressure stages under typical operating conditions. It is noteworthy that to every percentage point of air intake diverted for cooling there corresponds a reduction of engine thrust. Table 1, references 3 Russian.  
[262-2415]

UDC 621.165.001.2

#### ANALYTICAL PROFILING OF TURBINE BLADES

Moscow TEPLOENERGETIKA in Russian No 3, Mar 82 pp 63-65

DEREVYANKO, A. V. (dissertant), engineer, and KOPELEV, S. Z., doctor of technical sciences

[Abstract] An analytical method of designing the profile of turbine blades, also fan blades, is described and demonstrated on blades with a perimeter in the form of Bernoulli's lemniscate (curvature changes monotonically and collocation with a straight line occurs without discontinuity of the second derivative). The parametric equations of the curve are written in rectangular coordinates. The blade perimeter is approximated with partial lemniscates and straight-line segments on convex side and on concave side, both sides joined through circular arcs at the two ends. An array of circles is inscribed into the interior of the blade contour. All parameters determining the profile are adjustable through variation of coefficients in the describing equations. Curve fitting is effected through interpolation with a third-degree polynomial. The profile thus produced must meet the requirements of smoothness and geometrical compatibility with respect to characteristic points such as the center of gravity, centers of rounding circles at both ends, or center of largest inscribed circle. The distributions of velocity and aerodynamic coefficients around the profile are then estimated on the basis of a potential flow of a gas stream around the blade. The procedure has been programmed for an M-222 computer. The program contains a number of "Grafor" graphical subroutines for use with an ITEKAN-2MA plotter. The machine time is not more than 20 min for one profile. Figures 4, references 7 Russian.  
[252-2415]

## DEPENDENCE OF BLEEDER TAP PERFORMANCE ON DISTANCE BETWEEN TURBINE STAGES

Moscow TEPLOENERGETIKA in Russian No 3, Mar 82 pp 56-58

GOGOLEV, I. G., candidate of technical sciences, PEREVEZENTSEV, V. T., candidate of technical sciences, and MARKOV, K. Ya., engineer, Bryansk Institute of Transportation Machinery

[Abstract] Performance characteristics of a bleeder tap between two unregulated steam turbine stages are calculated on the basis of a given design configuration, taking into account their dependence on the distance between the stages. A zero air flow rate through the bleeder tap is assumed first. Then, for a typical  $\bar{G} = 0.33$  adjusted air flow rate through the bleeder, the optimum distance between the two stages is determined which will ensure most economical operation of the postbleeder stage. The pressure distribution in the stream before the postbleeder stage is also calculated so as to reveal the effect of the bleeder tap. Figures 3, references 4 Russian. [252-2415]

## DESIGN ANALYSIS OF STANDARD CYLINDRICAL MEDIUM-PRESSURE STAGE OF STEAM POWER TURBINES

Moscow TEPLOENERGETIKA in Russian No 3, Mar 82 pp 39-42

DORFMAN, L. A., doctor of physico-mathematical sciences, SERAZETDINOV, A. Z., candidate of technical sciences, LOPATITSKIY, A. O., candidate of technical sciences, LEVINA, S. R., engineer, YEVGEN'YEV, V. Yu., engineer, VOL'FSON, I. M., engineer, OZEROV, L. A., engineer, and SIMKIN, M. S., engineer

[Abstract] A quasi-spatial model of three-dimensional flow has been constructed for mathematical-experimental design analysis of power steam turbines involving successive approximations from mean-blade surfaces and average axisymmetric stream surfaces. Fringe losses are calculated on the basis of parabolic profiles in zones covering 1/3 of nozzle blade height and 2/3 of runner blade height. Narrow velocity peaks in the boundary layer at the entrance edge are taken into account on the basis of a generalized empirical relation. This model was used for a standard cylindrical medium-pressure stage with a  $d_m/l = 4.6$  ratio of median diameter to length. Calculations covered several modifications of the blade geometry, in the form of large undercuts, and various operating modes. The resulting output characteristics, efficiency vs referred tangential velocity at center of blade, and profiles of flow parameters over the blade height still do not agree closely enough with test data. This indicates a need for further

refinement of the model, taking particularly into account tapers and separation flow, to ensure a reliable optimum design. Figures 4, references 6 Russian.  
[252-2415]

UDC 621.224-156

THEORETICAL AND EXPERIMENTAL DESIGN STUDY OF RUNNERS FOR RADIAL-AXIAL  
HIGH-SPEED WATER TURBINES

Minsk IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: ENERGETIKA in Russian No 4,  
Apr 82 (manuscript received 26 May 81) pp 74-78

ALEKSANDROVA, T. A., candidate of technical sciences; STARITSKIY, V. G.,  
candidate of technical sciences; TOPAZH, G. I., candidate of technical  
sciences; and CHECHEL', N. S., candidate of technical sciences, Order of  
Lenin Leningrad Polytechnic Institute imeni M. I. Kalinin; plant facility  
for Higher Technical School at Industrial Association of Turbomachinery  
Manufacture "Leningrad Metal Works"

[Abstract] The problem of designing efficient runners for high-speed water  
turbines, with performance parameters corresponding to the optimum range  
on their dimensionless (universal) characteristic, is treated as one of  
combining theoretical analysis with experimental study. Altogether four  
variants of runners have been designed for nominal flow rate  $Q_1' = 1.5 \text{ m}^3/\text{s}$   
and speed  $n_1' = 100 \text{ rpm}$  at the Volkhovskaya GES, three of them tested and  
the last of those tested further modified for additional performance improve-  
ment. The first one was designed by solution of the inverse two-dimensional  
problem of constructing arrays of profiles on given axisymmetric flow sur-  
faces in a variable-thickness layer. Theoretical calculations and actual  
measurements included hydraulic losses (at guide vanes, at runner blades,  
losses in draft tube) as well as the velocity field in the stream. Also  
calculated was the efficiency-power output characteristic of a Volkhovskaya  
turbine operating with the last and best runner, indicating the feasibility  
of a 25-30% improvement of performance. It is still necessary to refine the  
estimates of eddy and impact losses as well as losses in the draft tube.  
Article recommended by Chair of Hydromachinery Design. Figures 3,  
references 5 Russian.  
[266-2415]



## SIMULATION OF HEATING OF RUNNER OF STEAM TURBINE IN TWO-DIMENSIONAL TEMPERATURE FIELD UNDER VARYING CONDITIONS OF HEAT TRANSFER FROM HOT STEAM

Minsk IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: ENERGETIKA in Russian No 4, Apr 82 (manuscript received 14 Apr 81) pp 55-60

POKHORILER, V. L., candidate of technical sciences, docent, and SHKLYAR, A. I., engineer, Order of Labor Red Banner Ural Polytechnic Institute imeni S. M. Kirov

[Abstract] The equation of transient heat conduction, in dimensionless time ( $H = \tau/\Delta\tau$ ) and cylindrical space coordinates  $(\rho, u)$ , is simulated on an analog computer for solution of the problem of a steam turbine runner in a two-dimensional temperature field with both steam temperature and convective heat transfer from steam to runner (Biot number) varying in time. The steady-state relation between temperature and Biot number is described by two known independent space functions and the transient temperature distribution over the runner is represented as a double sum of products of two linearly independent functions

$$t(\rho, u, H) - t_0 = \sum_{j=1}^2 \sum_{v=0}^{\infty} y_j^{(v)}(H) P_{jv}(\rho, u)$$

( $t_0$  - initial temperature,  $y_j(H)$  - external actions,  $y_j^{(v)}(H)$  - derivatives of external actions,  $P_{jv}(\rho, u)$  - functions of space coordinates). With such a temperature distribution, the fundamental differential equation of heat conduction reduces to two recurrent systems of differential equations for  $P_{jv}(\rho, u)$  with appropriate boundary conditions at surfaces sufficiently far to be in a uniform temperature field and thus not transferring any heat. With functions  $P_j$  known, the necessary relations between external actions  $y_j^{(v)}(H)$  and the two variables determining the runner heating  $t_{\text{steam}}(H)$ ,  $Bi_0(H)$  are established with aid of the Laplace transformation in the form of transfer functions. There are two variants of the resolvent equation possible and, correspondingly, two variants of the analog computer model are shown. Article recommended by Chair of Turbine Design. Figure 1, references 5 Russian. [266-2415]

## IMPROVING EFFICIENCY OF CONDENSATION-TYPE AND REGENERATIVE-TYPE POWER STEAM TURBINES

Minsk IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: ENERGETIKA in Russian No 4, Apr 82 (manuscript received 24 Dec 81) pp 42-49

BERMAN, L. D., doctor of technical sciences, professor, and  
YEFIMOKHIN, G. I., candidate of technical sciences, All-Union Thermotechnical Institute imeni F. E. Dzerzhinskiy

[Abstract] New condensers and regenerative preheaters are being developed at the USSR All-Union Thermotechnical Institute and at the U.S. Heat Exchanger Institute, also in the United Kingdom and in the Federal Republic of Germany, for the purpose of improving the efficiency of power steam turbines. The objective is better utilization of the heat transfer surfaces in both low-pressure and high-pressure stages, inasmuch as increasing the heat transfer coefficient is neither economical nor safe. Several configurations of heat exchangers have already been designed and tested for manufacture in the USSR, mixing being preferable to replacing brass with stainless steel in vertical U-tubes for higher corrosion resistance in feedwater with high oxygen content typical of 300 MW plants with steam at 23.5 MPa, 540°C. Another trend is toward predeaeration so that deaerators can be eliminated from the heat exchanger system. Figures 2.  
[266-2415]

## NAVIGATION AND GUIDANCE SYSTEMS

UDC 629.7.036

### OPTIMUM PROGRAM OF AIRCRAFT POWER PLANT CONTROL DURING ACCELERATION-CLIMB PERIOD

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA  
in Russian No 4, Oct-Dec 81 (manuscript received 28 Apr 78) pp 96-98

YUGOV, O. K.

[Abstract] During acceleration and climb the aircraft power plant is controlled by regulation of air intake as well as of compression ratio and gas temperature, which determine both engine thrust and fuel consumption. The optimality criterion is usually the total flight time or the total fuel requirement. Here the loss of range is selected as criterion, i.e. the extra distance an aircraft could fly cruising on the fuel spent for acceleration and climb. The optimum acceleration-climb trajectory is calculated from the corresponding Hamilton function of five control variables. In the case of subsonic aircraft the weight of fuel for acceleration and climb is only 3-5% of the total takeoff weight so that the weight of the aircraft can be assumed, without large error, to remain constant during this period. In the case of supersonic aircraft the weight of fuel for acceleration and climb is 10-12% of the total takeoff weight so that optimum control must take into account variable weight, say as function of the distance (altitude) predetermined for some operating condition such as peak engine power. Figures 2, references 1 Russian.

[240-2415]

UDC 62.50

### EVALUATING EFFICIENCY OF NONSTATIONARY DISCONTINUOUS AIRCRAFT CONTROL SYSTEMS

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA  
in Russian No 4, Oct-Dec 81 (manuscript received 24 Sep 79) pp 37-41

KUKLEV, Ye. A.

[Abstract] The stochastic version of a dynamic system with discontinuous control is considered under additional constraints of finite control time

( $T \ll \infty$ ) and finite number ( $\nu > 1$ ) of discontinuities during the system operating period  $(0, T)$ . The efficiency of such a control system is evaluated on the basis of some quality functional-criterion. The nonstationary dynamic system is assumed to be linear and the control discontinuities are described by switching of the matrix of dynamic coefficients in the corresponding homogeneous system of equations of motion. Considered successively are control with single discontinuity at an arbitrary instant of time, control without discontinuities but starting at random instants of time, control with single discontinuity and starting at random instants. Finally, the random flow switching instants in a system with finite number of discontinuities is treated as a nonuniform Poisson process of pure multiplication. References 4 Russian. [240-2415]

UDC 69-50:626:198.3

# SYNTHESIS OF OPTIMAL CONTROL FOR SPACECRAFT WITH ELASTIC ELEMENTS UNDER RANDOM PERTURBATIONS

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA  
in Russian No 4, Oct-Dec 81 (manuscript received 11 Nov 80) pp 23-27

DEGTYAREV, G. L. and LIFANOV, V. G.

[Abstract] A controllable spacecraft is considered which consists of a rigid central body with a pair of elastic cantilever elements vibrating in phase opposition. The accuracy of its stabilization depends on external perturbation moments. Gravitational and magnetic moments can be regarded as deterministic functions of orbit parameters, according to known analytical relations, so that their effects can be almost completely eliminated by proper control such as compensation. Aerodynamic and solar pressure moments must be regarded as random functions of time, possibly with zero mathematical expectation and constant spectral density. Optimal control of such a spacecraft under random perturbations is synthesized on this basis, using a distributed Kalman filter for estimation of the state variables and subsequent solution of the corresponding boundary-value problem with initial and final conditions. Measurement errors are treated as independent random "white" noise processes. A typical numerical synthesis of such an optimal control is shown which requires measurement of the rotation angle only. References 5 Russian. [240-2415]

## STABILITY OF MANEUVER AIRCRAFT

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA  
in Russian No 4, Oct-Dec 81 (manuscript received 16 Jun 80) pp 7-11

AMINOV, A. B.

[Abstract] Stability of controlled aircraft landing without thrust is analyzed by simulation of perturbed motion with a precise mathematical model containing nonlinear terms in the differential equations. The difficulty of constructing sign-definite functions can be overcome by use of quadratic forms in the functional space of specially matched nonlinear relations, in accordance with Lyapunov's theorem for linear approximations. The method is demonstrated on forward motion of a maneuver aircraft with large perturbations of angle of attack and pitching velocity. The asymptotic stability on-the-whole of the null solution to the corresponding system of equations for automatic pitch control is determined on the basis of the Barbashin-Krasovskiy theorem, and the Sylvester criterion of positive-definiteness is applied to the corresponding quadratic form. Figure 1, references 4 Russian.

[240-2415]

UDC 621.373:535(206.3)

PASSIVE Q-SWITCHING OF CO<sub>2</sub> LASER BY MEANS OF PHOTOCHROMIC FILTERS MADE OF HETEROCYCLIC COMPOUNDS

Leningrad OPTIKA I SPEKTROSKOPIYA in Russian Vol 52, No 5, May 82  
(manuscript received 2 Dec 80) pp 911-913

BUGAYEV, V. A. and SHLITERIS, E. P.

[Abstract] Radiation from a CO<sub>2</sub> laser was Q-switched experimentally by means of various pairs of heterocyclic (penta-, hexa-) organic compounds: 1,3 and 1,4-dioxane C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>, thiophene C<sub>4</sub>H<sub>4</sub>S, tetrahydrofuran C<sub>4</sub>H<sub>8</sub>O, pyridine C<sub>5</sub>H<sub>5</sub>N, each pair modulating different series of lines. The absorption coefficient  $\alpha = \log \frac{I_0}{I_{PL}}$  did not exceed a few 10<sup>-3</sup> cm<sup>-1</sup> torr<sup>-1</sup>

(I, I<sub>0</sub> intensities of incident and transmitted radiation respectively, p- pressure in absorption cell, L- length of absorption cell). The pressure range of passive Q-switching was found to vary from several tens to several hundreds of millitorrs, depending on intensity of laser line and on absorption power of filter. At low pressure Q-switching occurs at maximum possible absorption, near the center of the absorption band. With increasing pressure its frequency range first widens toward weaker absorption and then again narrows, with attendant decrease of pulse repetition rate, till complete cutoff. Figures 3, references 6: 2 Russian, 4 Western. [269-2415]

EFFECT OF PERTURBATION IN ACTIVE MEDIUM ON FREQUENCY INSTABILITY OF  
EMISSION FROM STABILIZED LASER WITH EXTERNAL ABSORBING CELL

Leningrad OPTIKA I SPEKTROSKOPIYA in Russian Vol 52, No 5, May 82  
(manuscript received 4 Jul 80) pp 904-908

MIRONOV, A. V., PRIVALOV, V. Ye. and CHULYAYEVA, Ye. G.

[Abstract] A helium-neon laser ( $0.63 \mu\text{m}$ ) with frequency stabilization through automatic frequency control and with an absorbing neon cell inside a solenoid is considered, of specific interest being the effect of perturbations in the active medium on the frequency stability of emission from such a laser. The main source of such perturbations is modulation of the discharge current with resulting fluctuation of the refractive index. Another cause of frequency instability is frequency modulation of the longitudinal magnetic field in the solenoid, resulting in a split of the absorption contour. Theoretical expressions are derived for the frequency error of laser emission, in the normal case of only small variation of this error over a period of the light wave owing to inertia of the automatic frequency control system and in the general case of a difference between frequency of magnetic field modulation and frequency of active medium modulation. Measurements were made in an experiment with an LG-149-1 laser and a feedback loop consisting of absorption cell inside solenoid, modulator of magnetic field, synchronous detector, d.c. amplifier, and piezoelectric frequency corrector. Readings taken with a photoreceiver diode through a voltage amplifier, across absorption cell and synchronous detector, give the dependence of laser frequency instability on frequency and percentage discharge current modulation as well as on the averaging time. The results confirm the theory. The author thanks S. Ya. Pakhin for participating in the experiment. Figures 5, references 10: 9 Russian, 1 Western.  
[269-2415]

UDC 533.6.011

ASYMPTOTIC SOLUTION TO PROBLEM OF SHOCK WAVE IN HYPERSONIC STREAM AROUND  
AXISYMMETRIC BLUNT BODIES

Leningrad VESTNIK LENINGRADSKOGO UNIVERSITETA: MATEMATIKA, MEKHANIKA,  
ASTRONOMIYA in Russian No 7, Issue 2, Apr 82  
(manuscript received 17 Sep 81) pp 26-32

RASPORSKIY, V. A. and ENGEL'GART, V. N.

[Abstract] The problem of a shock wave in a hypersonic stream around an axisymmetric blunt body, with Mach number  $M_\infty \leq \infty$  and effective adiabatic exponent  $\lambda \rightarrow 1$ , is solved by asymptotic integral iterations with respect to the small parameter  $\varepsilon = (\lambda - 1)/(\lambda + 1)$  and the correction parameter  $\eta = M_\infty^{-2}$ . The equations of gas dynamics in  $b$ - $\tau$  coordinates ( $\psi$  - flow function,  $x_b = f(y_b)$  equation of body contour,  $b^2\tau^2 = 2\psi$ ) are integrated in part and solved accordingly for the region up to the separation point  $b = b_0$  at a body contour describable by the function

$$x_b = \frac{f_2}{2!}y_b^2 + \frac{f_4}{4!}y_b^4 + \frac{f_6}{6!}y_b^6 + \frac{f_8}{8!}y_b^8 + O(y_b^{10})$$

( $f_{2,4,6,8}$  - body form factors). The shock wave is described by functions

$\delta, \varphi, \tau_s$  ( $\delta$  - departure of shock wave from body contour,  $\varphi$  - angle between direction of shock wave and axis of body), to which is added the function

$$n = \varepsilon b^2 \int_0^\tau (\varepsilon \rho v_w y)^{-1} dt \quad (\rho - \text{density of gas, } v_w - \text{velocity of shock wave}).$$

The first approximation has already been constructed, here the second approximation is constructed for better accuracy. The results of calculation are comparable with those obtained by direct numerical solution of the problem for  $\lambda = 1-1.4$  and  $M_\infty = 3, \infty$ . Tables 4, references 8 Russian.  
[265-2415]



## THEORY OF REGULAR FLUCTUATIONS IN SWIRLING STREAM OF FLUID

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKNIKA  
in Russian No 1, Jan-Mar 82 (manuscript received 26 Nov 80) pp 83-89

KNYSH, Yu. A. and URYVSKIY, A. F.

[Abstract] Buildup of a vortex in strongly swirling stream of liquid or gas is analyzed on the basis of a theoretical model which assumes an incompressible fluid and a vortex-free flow over the entire cross section except within a narrow annulus. The fluid is also assumed to be ideal and, therefore, the boundaries of the turbulent annular layer to be nonrigid. The equations of motion have been solved by simulation on an M4030 computer, with judicious application of conservation laws, for tracking the evolution of point vortices into vortex clusters and a filament radially eccentric with respect to a stream in bounded space. Regular precession of such a vortex is established theoretically on this basis and stability of its motion is tested. With the aid of experimental data characterizing conditions in an aircraft gas turbine engine, empirical expressions are derived for the frequency and the amplitude of fluctuations as elementary functions of the twist. Figures 3, references 8: 5 Russian, 3 Western.  
[262-2415]

## MECHANICS OF SOLIDS

### NONLINEAR VIBRATIONS OF PLATES IN LONGITUDINAL MAGNETIC FIELD

Yerevan IZVESTIYA AKADEMII NAUK ARMYANSKOY SSR: MEKHANIKA in Russian  
Vol 35, No 1, Jan-Feb 82 (manuscript received 14 Dec 79) pp 16-22

BAGDOYEV, A. G. and MOVSIYAN, L. A., Institute of Mechanics, ArSSR  
Academy of Sciences

[Abstract] One-dimensional vibrations in cylindrical flexure of a physically nonlinear elastic plate in a longitudinal magnetic field are analyzed, assuming the plate material to be an ideal conductor. The dispersion relation is derived from equations of motion for the two-dimensional problem and equations of electrodynamics with a Lorentz force, in the small-displacements approximation. Calculations according to the classical theory in Lagrangian coordinates yield the same result as long-wave refinement of the theory. References 8: 7 Russian, 1 Western.  
[263-2415]

UDC 539.3

### THEORY OF THIN ANISOTROPIC SHELLS MADE OF COMPOSITE MATERIALS

Leningrad VESTNIK LENINGRADSKOGO UNIVERSITETA: MATEMATIKA, MEKHANIKA,  
ASTRONOMIYA in Russian No 7, Issue 2, Apr 82 (manuscript received 18 Jul 81)  
pp 32-37

RODIONOVA, V. A.

[Abstract] A shell made of composite polymer material is treated as a thin elastic anisotropic body and the corresponding three-dimensional boundary-value problem for stresses and strains (displacements) according to the linear theory of elasticity is reduced to a two-dimensional one by the novel method of weighted deviations. The solution for static boundary conditions at the base surfaces is sought with aid of Cauchy relations and generalized Hooke's law. In a typical case of five unknown displacement functions, with terms of a power series used as weight functions, the zeroth-order and the first-order moments of deviations in the first two equations of equilibrium together with the zeroth-order moment of deviation

in the third equation of equilibrium yield a tenth-order system of partial differential equations of equilibrium. The problem can be discretized according to a difference or variational difference scheme. The first approximation represents a theory not much more intricate than the classical theory without deficiencies of the latter. For solution of the dynamic problem it is necessary to supplement the boundary conditions with initial conditions. References 6 Russian.  
[265-2415]

UDC 539.4.629.7.02

#### DESIGN OF STRAIGHT-WING SHELLS

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA  
in Russian No 4, Oct-Dec 81 (manuscript received 16 Mar 80) pp 80-83

BULATOV, S. N. and KUROCHKA, P. N.

[Abstract] Modern aircraft wings are designed as shells of variable thickness, the latter varying both along the span and across the chord. Here, for the design of such a wing shell of arbitrary cross section, the resolvent system of equations is derived from Lagrange's variational principle. The solution is sought in form of series, where the first terms correspond to the hypothesis of plane sections and the remaining terms account for displacements caused by warping. Stresses and strains at any point are calculated for boundary conditions of rigid clamping, as functions of geometrical ratios. Numerical results are shown for a caisson of elliptical cross section and linearly varying thickness loaded at one end by a twisting moment. The method can be extended to wings with reinforcing stringers of variable cross-sectional area and to sweptback wings. Figures 4, tables 2, references 4 Russian.  
[240-2415]

UDC 539.3

#### DESIGN OF CYLINDRICAL SHELL WITH SHAPE IMPERFECTION FOR STABILITY UNDER AXIAL COMPRESSION ON BASIS OF BUCKLING PATTERN ESTABLISHED BY TEST DATA ANALYSIS

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA  
in Russian No 4, Oct-Dec 81 (manuscript received 22 May 81) pp 56-60

TEREGULOV, A. G.

[Abstract] Thin cylindrical shells with shape imperfection are designed for stability under axial compression on the basis of the most dangerous initial depression, namely the one whose shape and amplitude determine the subsequent waviness pattern under load. Calculations start from linearized

equations of subcritical flexure and static stability, with the modes of initial and subcritical deflections assumed to be similar to that of the deflection increment at first instant of buckling. This method of design is demonstrated on a thin cylindrical shell of medium length with an initial depression within the central part. According to experimental data, the waviness due to buildup of the initial depression under load attenuates very fast so that the critical load in axial compression does not significantly depend on the boundary conditions. The problem of subcritical flexure under axial compression is solved by the Bubnov method for the state of stress and strain. The results are illustrated with a numerical example. References 7: 6 Russian, 1 Western.  
[240-2415]

UDC 539.374

#### ULTIMATE EQUILIBRIUM OF CYCLICALLY SYMMETRIC SHELLS

Tashkent IZVESTIYA AKADEMII NAUK UZBEKSKOY SSR: SERIYA TEKHNIЧЕСКИХ НАУК in Russian No 6, Nov-Dec 81 (manuscript received 25 Nov 80) pp 33-37

DEKHTYAR', A. S., Kiev State Art Institute, and YADGAROV, D. Ya., Bukhara State Pedagogical Institute imeni S. Ordzhonikidze

[Abstract] The upper limit of critical load is estimated for a shallow shell resting on a circular base, the median surface of this shell having an arbitrary radial profile but cyclic symmetry with respect to the axis. The shell thickness and the transverse load are distributed arbitrarily, also the shell constraint at the base is arbitrary but does not violate the cyclic symmetry. The ultimate equilibrium of such a shell is found by the kinematic method, considering that an ideal rigid plastic material has a different yield strength in tension and in compression independently determined by internal force factors. Equating the dissipation of mechanical energy during plastic deformation to the virtual work of external forces yields the upper estimate of critical load in the form of a functional minimizable with respect to three displacement vector components (radial, normal, tangential) in the set of kinematically safe fields of possible displacements. All three displacement components are assumed to be zero in the case of a shell with rigid constraint at the base. The functional is minimized numerically with use of a discretization grid. As an example, the procedure has been applied to a shell generated by rolling a right circular cone around a similar stationary one and approximately described by the equation

$$Z = \gamma R = r \cot(\beta + 2\theta \bmod \sin \frac{\theta}{2})$$

The algorithm has been programmed in FORTRAN input language for the "Dubna" operating system. Figures 2, table 1, references 3: 1 Russian, 1 Polish, 1 Western.  
[255-2415]

## CALCULATION OF PARAMETERS OF SOLID-BODY ORIENTATION

Kiev DOKLADY AKADEMII NAUK UKRAINSKOY SSR, SERIYA A: FIZIKO-MATEMATICHESKIYE I TEKHNICHESKIYE NAUKI in Russian No 4, Apr 82  
(manuscript received 3 Apr 81) pp 27-31

LEBEDEV, D. V., Institute of Cybernetics, UkSSR Academy of Sciences

[Abstract] The orientation of a solid body can be determined from readings of angular-velocity transducers mounted on it. Here the feasibility of constructing general algorithms for calculating the orientation parameters is examined with the aid of abstract algebra. The position of the associated trihedron relative to the inertial basis is described by a matrix of direction cosines, and Poisson equations of motion are written in the form of a corresponding matrix equation. The latter is differentiated with respect to time, which yields a solution in the form of a product of two matrices corresponding to the conventional kinematic equations in Krylov angles. One of the matrices in the product is orthogonal and can be transformed according to the Campbell-Hausdorff relation, its elements being the coordinates of the orientation (true rotation) vector, while the angular velocity read at discrete instants of time can be expanded in a Taylor series in the vicinity of time  $t = t_0$ . The orientation parameters are then calculated by the Picard method of successive approximations. This procedure yields general structures depending on how the error on each step is characterized; one of a five-parameter family of algorithms with third-order precision and one of a nine-parameter family of algorithms with fourth-order precision. The choice of algorithm will be determined by the precision requirement and the computer capability. Article was presented by Academician A. I. Kukhtenko, UkSSR Academy of Sciences. References 5 Russian.  
[256-2415]

## APPROACH TO NUMERICAL SOLUTION OF BOUNDARY-VALUE PROBLEMS IN STATICS OF FLEXIBLE SHELLS

Kiev DOKLADY AKADEMII NAUK UKRAINSKOY SSR, SERIYA A: FIZIKO-MATEMATICHESKIYE I TEKHNICHESKIYE NAUKI in Russian No 4, Apr 82  
(manuscript received 27 Nov 81) pp 21-24

GRIGORENKO, Ya. M., corresponding member, UkSSR Academy of Sciences, and KRYUKOV, N. N., Institute of Mechanics, UkSSR Academy of Sciences

[Abstract] A new approach is taken to solution of boundary-value problems for geometrically nonlinear subcritical and supercritical deformation of

flexible shells. It involves transformation of the original problem, written in the form of a vector equation, to a homogeneous system and quasi-linearizing the latter according to an appropriate iteration scheme which yields a sequence of linear boundary-value problems. The validity of this procedure has been proved for an infinitely long and uniformly thick circular cylindrical panel under a normal surface load, by comparing the results with those of the exact solution. It is now applied to a frustum of a uniformly thick ellipsoidal shell of revolution, rigidly clamped outside and free inside, under normal pressure. Figures 2, references 8 Russian.  
[256-2415]

## TESTING AND MATERIALS

UDC 620.178.16:621.833

### WEAR RESISTANCE OF GEAR TRANSMISSIONS IN VACUUM

Moscow VESTNIK MASHINOSTROYENIYA in Russian No 3, Mar 82 pp 18-19

NAZHESKIN, B. P., candidate of technical sciences, and SMIRNOV, N. I.,  
candidate of technical sciences

[Abstract] An experimental study was made of cylindrical gear transmissions ( $m = 1$  mm,  $z_1 = 39$ ,  $z_2 = 81$ ) to determine their wear resistance in vacuum when operating dry, with plastic lubricant (VNII NP-220) and with solid-lubricant coating (VNII NP-230). The gear material was 07Kh16N6 steel, the pinion material was either 07Kh16N6 steel or self-lubricating S820 alloy (80% Fe + 16% Cu + 4% Pb), teeth hardened to  $HR_c = 34-45$ . The test stand with a closed force loop was put inside a vacuum chamber with the pressure sliding from  $10^3$  to  $10^{-3}$  Pa at  $25^\circ\text{C}$ . The sliding velocity was varied over the 0.21-0.86 m/s range under loads corresponding to the 100-400 MPa range of contact pressure at teeth. The wear rate was evaluated according to the relation

$$J = \frac{d\delta}{ds} \approx \frac{\delta}{s} \quad (\delta, \text{ mm} - \text{thickness of layer worn away; } s, \text{ mm} - \text{path of}$$

sliding friction). The data, based on  $3 \cdot 10^3$  loading cycles under vacuum of  $10^{-3}$  Pa, fit the approximate empirical relation  $J = \alpha \omega_N^{\alpha} / \text{mm}^{\alpha} v_m^{\beta} / \text{s}^{\beta}$  with coefficient  $\alpha$  and exponents  $\alpha$ ,  $\beta$  depending on tooth material and lubricant. Figure 1, table 1, references 5 Russian.

[253-2415]

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